E Jones

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FILE: EVA DEVELOPMENT

GUIDELINES FOR EVA DEVELOPMENT

MANNED SPACECRAFT CENTER
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PROJECT DOCUMENT COVER SHEET

GUIDELINES FOR EVA DEVELOPMENT

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PREPARED BY:	Larry E. Bell Extravehicular Equipment Development Branch
APPROVED:	Crew Systems Division
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GUIDELINES FOR EVA DEVELOPMENT

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1.0 PURPOSE: The purpose of this document is to present the EVA Program guidelines along which the NASA should operate as it identifies and pursues its long range goals.

The guidelines herein will serve to identify the objectives of the EVA development program, identify the areas of technology requiring investigation, and establish the managerial and implementing organizations.

2.0 PROGRAM OBJECTIVE: The primary objective of this program is the development of EVA capabilities to the extent that EVA is established as a useful operational technique, competitive with other techniques, for accomplishing certain tasks. A unified program throughout the NASA will be implemented, thereby eliminating duplication, providing more efficient utilization of facilities and manpower, and unifying the efforts of the various groups and centers toward a single goal. This program will provide for the timely evaluation and development of techniques, methods, and hardware required to establish the capabilities to perform these tasks.

2.1 Background: The Gemini Program proved the capability of man to function in the free space environment external to the relative safety of the spacecraft cabin. Gemini also demonstrated that man can perform useful tasks while EVA, but that these tasks must be carefully evaluated, planned, performed within certain limits, and supported by the proper use of the proper equipment.

Gemini experience underscored the need for a carefully planned program of study into the problems associated with EVA and the need for a well defined program to develop EVA into an acceptable operational mode. The Gemini XII flight is considered to be the first step in this direction.

2.2 Philosophy: It is felt that most tasks, with the exception of lunar exploration, free space (i.e., undocked CM and LM), vehicle-to-vehicle transfer, and certain specific inspection, maintenance, repair, and erection tasks can be performed in some manner other than by the

use of EVA. This program plan is based on the premise that EVA is an accepted method for accomplishing these tasks and that it should be utilized in those instances where trade-off studies show that performance of the task can best be done by EVA, rather than by some other method. For example, materials recovery in support of an experiment might be performed EVA or a remotely operated system could be employed. EVA would be employed if the cost, complexity, operational characteristics, etc. of the mechanical retrieval system were found to be undesirable.

2.3 <u>Program Development</u>: This program is developed in such a manner as to provide for the timely evaluation and development of techniques, methods, and hardware required to provide the capabilities necessary to support performance of the expected tasks. This program also provides for the development of new hardware and techniques, taking advantage of state-of-the-art advancements, to provide extended capabilities. The development of these techniques, methods, and hardware would be divided into the broad categories of life support systems, crew and equipment mobility, and work site technology.

2.3.1 <u>Task Development</u>: The majority of major tasks such as activation, inspection, maintenance, and repair, etc. of orbiting structures can be broken down into discrete subtasks such as making and breaking electrical connectors, removing or attaching components, translating from one point to another, remaining in the desired attitude at a desired point, etc. The development of EVA as a useful operational tool should include a continuing program of evaluating these expected subtasks, both in one 'g' and in zero 'g' or 1/6 'g'. A major portion of the extravehicular activity performed on the Gemini XII mission was devoted to this type of evaluation.

The desirable program for developing EVA subtasks, tasks, and procedures should consist of the following steps, where applicable:

a. Determination of general requirements
b. Analysis of requirements to define specific tasks
c. One 'g' walkthroughs and evaluations
d. Neutral buoyancy evaluation
e. Zero 'g' or 1/6 'g' evaluation in aircraft
f. Zero 'g' or 1/6 'g' evaluation in pressurized orbital workshop
g. Zero 'g' or 1/6 'g' evaluation or performance in the space vacuum

It is expected that only those tasks demonstrated within the previously developed capabilities will be programmed for operational accomplishment in a particular mission. These capabilities include hardware as well as procedures.

The program is intended to develop, in as far as possible, the techniques and hardware such that the capability to perform a task EVA is available, if required. It does not provide for a mission dependent program whereby techniques and hardware are developed to meet a specific purpose. Such development to support a mission requirement would be carried out by the appropriate center(s).

3.0 <u>IMPLEMENTATION</u>: The EVA development program shall be implemented in the following manner:

a. Establishment of an organization to direct EVA development.

b. Assessment of the present level of technology and capabilities.

c. Establishment of programs to develop the basic technology required in the three prime technology areas: life support, crew and equipment mobility, and work site aids.

d. Establishment of programs integrating the three basic technologies to evaluate and develop task performance capabilities.

e. Establishment of standards and criteria for the design of hardware and development of procedures.

f. Establishment of an information dissemination program.

3.1 Present Level of Technology: The present level of EVA technology must be determined in order to provide a baseline from which future programs can be developed. Various reports and documentation exist concerning past and present programs. The initial effort should be made to establish the present level of technology by:

a. Compiling a summary of U. S. and Soviet EVA results including equipment used, capabilities developed, and accomplishments. This information can be gleaned from films, journals, the "Gemini EVA Summary Report" (NASA), the "EVA Systems Criteria" (NASA), etc.

b. Description and assessment of EVA simulation and training techniques and capabilities of the various industry and Government facilities.

c. Description and assessment of past, present, and planned EVA support equipment such as suits, environmental control systems, maneuvering aids, cameras, communications equipment, etc.

d. Description of EVA technology areas which need expansion.

3.2 Task Requirements and Rationale for Technology Selection: As future space missions become more ambitious, the astronaut will be required to perform activities which will be essential to mission success. For example, currently envisioned earth orbital missions may involve erection of telescopes and antennas for use in studying astronomy, advanced communications, and earth sciences and resources. Eventually, more permanent manned orbital stations will be in use which must be maintained and resupplied. In the more distant future, manned planetary missions will be undertaken with tasks involving maintenance, repair, inspection, assembly, fueling, and other activities. The capability required to support these missions will depend, among other things, on the astronaut's ability to efficiently operate in an EV environment. Man's operational capability to perform these EV activities is a key factor in preparing for these advanced missions and must be developed along with other important technology areas. The task of developing these capabilities requires a logical and well organized approach. Appendix 1 is an analysis of the EVA tasks and requirements which is based upon Gemini EVA experience, mission planning for Apollo and AAP, and reasonable predictions of extravehicular requirements for post-AAP missions.

Figure 1 represents in block format the approach utilized in categorizing the future EV requirements into three major technologies.

First, the operations which utilize EVA support of future manned missions were reviewed, analyzed, and defined in terms of functional tasks to be done by the astronaut. From this analysis the EV requirements (locomotion and maneuvering, maintenance and repair, assembly, etc.) required to conduct specific missions were identified. These major requirements are identified in column 1, Figure 1, page 16. Although each of these categories have both unique and common elements, each area can meet the test of "does it stand alone as an end item requirement?" The last category, rescue, does not meet this requirement, but is included as it is a resulting requirement of EVA.

The next step was to analyze each of these categories into major crew functions and hardware and then synthesize these into common functions and hardware capabilities. These common crew functions and hardware represent capabilities which must be developed in an evolutionary manner if the astronaut is to perform the requirements identified in the first column.

The final step in the organization sequence is depicted in column 3, Figure 1, which represents a synthesis of these common capabilities into three major extravehicular technologies. The development of ultimate long-range operational capability to perform EVA begins now with ground and orbital based experimentation scoped toward the investigation of these fundamental technologies.

3.3 <u>Technology Development Program:</u> The development of the capabilities to perform the EVA tasks of column 1, Figure 1, is based on the thorough investigation and development of the three basic technologies of column 3, Figure 1. It must be emphasized, however, that the technology development programs must be directed toward development of the common capabilities of column 2, Figure 1, which

in turn result in the capabilities to perform the EVA task requirements of column 1. It is encumbent then on the organizations responsible for the technology development to insure that programs are not directed solely toward the development of capabilities to perform the EVA tasks such as inspection, maintenance and repair, assembly, etc.

Figure No. 2, page 17, illustrates the relative development status of the three basic technologies. As the chart shows, preparation for and use during flight contribute sequentially from program to program. Life support technology (which includes suits and environmental control equipment) will probably be developed more extensively than the other two areas during Apollo and AAP for operational support. Figure No. 3, page 18, shows expansion of life support technology by equipment type. Advanced missions, however, incorporating the complex capabilities of Figure No. 1, will require comprehensive knowledge and experience in the areas of mobility and worksite operations. Therefore, it is necessary to schedule prior contributing experimental endeavors in these areas, and these are shown as "Orbital Workshop (OWS) Experiments" in Figure No. 2.

3.3.1 Life Support Systems: The development of life support systems for extravehicular activity is being directed toward the production of space suits capable of supporting a wide range of EV missions and incorporating the required mobility and protective measures essential to successful EVA and toward the production of compact environmental control systems incorporating high heat load capability, simplified recharge capability, high density storage of oxygen, and indefinite shelf life. In addition to suit and ECS development, communications and bioinstrumentation systems must be developed to assure adequate monitoring of crew activities and physiological state.

3.3.1.1 Space Suit Development: The NASA space suit development program is structured such that it can support a very wide range of missions. In addition to the Apollo Block II suit, which is being developed toward a specific mission objective, MSC

has programmed and are presently pursuing the establishment of three distinct EVA space suit configurations.

a. Orbital Extravehicular Space Suit: For use in the orbital extravehicular activity environment, it is planned that a constant-volume mobility system be incorporated into a soft fabric protective pressure vessel which will provide the superior qualities of the constant-volume concept and yield a reduced weight and stowage volume when compared with hard-structured suits.

b. Hard Structure EVA Suit: Due to the extreme hazard of lunar surface exploration, it is desirable to provide a space suit assembly which can withstand severe abrasion and wear and will remain serviceable after numerous EVA missions. To accomplish these goals, the hard structure EVA suit is being configured to embody a "hard structure" pressure vessel in combination with low torque, constant-volume mobility systems which will provide long service life for the extended lunar stay requirements.

c. Integrated Space Suit, ECS, and Propulsion System: For EVA, it is highly desirable that the capability exist to provide the EVA crewman a protective system utilizing minimum connections and external attachments. The integration of the space suit, the ECS, and the propulsion system is designed to provide the EVA crewman with a single life support protective assembly for the EVA mission. The integrated concept would use either the constant-volume soft suit or the hard structure space suit configuration.

"Off-the-shelf" availability of these space suit configurations will permit the quick and effective matching of qualified space suit equipment to the requirements of any NASA assigned lunar surface, lunar orbit, or earth orbital mission.

Supporting the major suit configuration programs, there is intensive subsystem development being accomplished on important problem areas. These areas include such subsystems as helmets, visors, body cooling garments, EVA gloves, and waste management systems. Studies in the areas of suit mobility, advanced hard suit development locomotion in reduced gravitation, etc., should be pursued and the results fed into the suit development on a timely basis.

3.3.1.2 ECS Development: The Apollo Portable Life Support System (PLSS) has been designed for the mainstream Apollo lunar landing mission. The PLSS will be modified to provide for umbilical supply. This modified PLSS will support EVA on AAP missions 1 through 4.

The Portable Environmental Control System (PECS) is currently under development and could be a backup system for AAP missions 1 through 4 and as the flight system for subsequent missions with the exception of the Apollo lunar landing mission. The basic PECS will be capable of 9000 Btu total heat rejection and will incorporate a 7500 psi gaseous oxygen supply as backup to the spacecraft umbilical supply or as the normal supply for umbilical-free operations.

A sodium chlorate candle oxygen supply system is presently in development and will allow high density O_2 storage, indefinite shelf life, and simple recharge for later long duration mission requirements such as AAP lunar exploration and space station missions.

Concurrently with the $NaClO_3$ candle development, a cryogenic oxygen supply system will be developed to support a demand-type oxygen supply which will allow a reduction in PECS pack weight and volume.

A regenerable heat rejection system will be developed to allow multi-excursion EVA weight saving by eliminating water recharge requirements.

The basic PECS (gaseous O_2) will be utilized for missions through mid-1971. An improved PECS design, incorporating inputs from previous missions and either the $NaClO_3$ or cryogenic oxygen supply (depending on mission requirements) and a regenerable heat rejection system, will be available for AAP lunar exploration and long duration space station missions.

Extended lunar operations and Mars planetary fly-by missions can be supported by a PECS with an advanced regenerable heat rejection system.

An umbilical system is being developed to support the modified PLSS (or PECS) for AAP missions 1 through 4. An advanced umbilical optimizing weight, volume, and rigidity will be developed which will be used for missions subsequent to AAP missions 1 through 4. It is expected that this advanced umbilical design will include composite electrical, gas, and water connections.

The advantages of a small open-loop life support system of the type used on Gemini IV have been recognized; the most important of these advantages being minimum volume. However, weight penalties are paid for during extended EVA. An open-loop system is being developed for AAP missions 1 through 4 to support those experiments performed in the pressurized S-IVB tank and requiring the crewman to be in a pressurized suit.

In addition to these hardware developments, basic research in the areas of CO_2 tolerance in man, liquid cooled garment (LCG) performance, automatic temperature control of LCG inlet H_2O, etc., should be performed and the results utilized in optimizing ECS design.

3.3.2 Crew and Equipment Mobility: Practically speaking, crew and equipment mobility encompasses such activities as translation along a handrail by an extravehicular astronaut, remotely controlled maneuvering of cargo in space, and traverse of the lunar terrain, etc.

The necessity for extravehicular mobility is obvious if useful work involving men and materials is to be performed outside habitable enclosures. Erection, activation, inspection, repair, and maintenance operations all may require direct participation by an extravehicular crewman. Also, safety considerations impose the necessity of determining means of rescue of stranded crewmen. Such operations may be carried out in orbit or on the lunar surface, and crew or cargo transfer systems will be vastly different for these two environments.

There is another and more basic subdivision, however, and this is the categorizing of mobility devices into:

a. Those utilizing reactive thrust for translation and some reactive or momentum conservation approach for attitude control.

b. Those using direct link techniques.

The Gemini Program provided the first real opportunity to develop and demonstrate crew mobility hardware of both types.

The MSC developed hand-held maneuvering unit was the only system of category A type actually used, and its evaluation, while limited, was encouraging. The need for maneuvering and control capability was made evident by the lack of control encountered by the extravehicular crewmen when attempting to maneuver using the life support umbilical.

The Air Force D-12 Astronaut Maneuvering Unit (AMU) was a sophisticated translation/stabilization system which was to have demonstrated the capabilities of an all-thruster maneuvering system.

Another approach to providing such independent maneuvering capability which has been under study and development is a system using momentum exchange between gyroscopes and the man to achieve attitude control, and thrusters for translation (and gyro desaturation).

Surface mobility devices are under study for lunar surface operations - crawlers or wheeled roller vehicles and flying vehicles.

Direct link devices such as expandable or roll-out rods appear to have merit for short distance transfer (under 50'). Simplicity and low weight are principal advantages.

There is need to develop a family of hardware concepts so that the definition of a mission application can be used as a source for the selection of a suitable hardware approach for flight. This development should be based on a well-coordinated program of definition, ground-based simulation and zero 'g' or partial 'g' experimentation.

3.3.3 Work Site Technology: An effective means of restraining the extravehicular crewman is a prerequisite to the performance of useful work in zero 'g' and will be required for specific tasks in

lunar 'g'. Gemini IX-A EVA experience underscored the need for extensive evaluation of methods of restraining the crewman. Of prime importance are the tools and manipulative devices required in performance of particular tasks. Evaluations, both ground-based and zero 'g', similar to those done on Gemini XII, should be performed on a continuing basis as new techniques such as reactionless tools, capsular and magnetic adhesives, control momentum gyro systems, etc. are developed.

A vigorous program to develop the necessary restraint & stability aids, illumination aids, and tools should be established aimed at developing the capability to perform maintenance, repair, assembly, etc. Without proper work site aids, performance of useful EVA tasks will be impossible.

3.4 Standards and Criteria and Information Dissemination: The vast amount of study, development, and test work carried out during the exploratory activities of extravehicular technology areas will accumulate information on: (1) performance limitations and capabilities of man and equipment and (2) proven methods and techniques for analysis, simulation, and test. Flight experience will identify certain rules and principles which should be used in design, test, training, etc. Therefore, one of the features of the EVA development program should be the initiation, imposition, and maintenance of standards and criteria specifically geared to EVA hardware and techniques. Examples of areas to be covered are: (1) organization of a standard space suit evaluation procedure; (2) establishment of design guidelines for crew equipment which stress crew safety and operational utility; (3) rules for use of toxic or corrosive propellants in the vicinity of the space suit; and (4) rules for categorizing the relative criticality of various equipments and determining the required degree of redundancy or backup.

Data dissemination will be necessarily preceded by a data gathering, reduction, and organization process. This process will require the participation of many EVA-related NASA, DOD, and industrial activities. These data should then be distributed to appropriate agencies automatically.

In addition to reports and papers, engineering level motion pictures to include key tests, flight results, and concepts should be made.

The first step in such a process is exemplified in the compilation and distribution of the special report, "Summary of Gemini Extra-vehicular Activity, " (MSC-G-R-67.2).

4.0 ORGANIZATION AND RESPONSIBILITIES:

4.1 Manned Space Flight Extravehicular Activity Development Board (MSF/EVADB): The MSF/EVADB will comprise a committee representing the following: Office of Manned Space Flight (OMSF), chairman; Office of Advanced Research and Technology (OART); Langley Research Center (LRC); Ames Research Center (ARC); Marshall Space Flight Center (MSFC); and Manned Spacecraft Center (MSC). In addition, the Board will include membership from the Department of Defense (DOD) and Office of Space Science and Applications (OSSA), (NASA) (but not limited to) as required on a consulting nonvoting status. This group will meet quarterly and will exercise the following responsibility:

a. Initiation, overall program control and monitoring of EVA programs, and through its Advanced Mission Program and Space Medicine Offices, assurance that close coordination is maintained between its EVA program and other organizations directly involved.

b. Identification of mission oriented programs requiring EVA.

c. Definition of early ground-based or orbital experiments needed to verify mission concepts/designs, supporting equipment proposed, and operational mode selection.

d. The creation of a long range EVA program schedule for development of EVA operational capability.

4.1 Certain detailed activities shall be accomplished either by the Board or by working committees established by the Board as required.

4.1.1 Extravehicular Activity Development:

a. Initiation and maintenance of an extravehicular standards and criteria handbook which defines man's capabilities and man/machine design criteria applicable to EVA.

b. Insurance that medical requirements are established. This includes determination of practical limits of man's performance capabilities with respect to imposed work loads and environmental stresses, and determination of the hardware requirements to monitor and indicate astronaut well being and level of energy expenditure.

c. Flight safety - monitor all EVA efforts to insure that safety of the extravehicular crewman is the prime consideration in any development or operational effort.

d. Act as liaison between operating groups to insure that close coordination is maintained with respect to program objectives. This activity will involve the preparation of an overall EVA development schedule integrating programs in the Life Support, Crew and Equipment Mobility, and Work Site Technology areas.

e. Aid in mission planning and determination of how EVA might be employed in support of specific missions. This activity will provide continual support in the areas of detailing mission objectives and of providing up-to-date information to program managers as to the current level of extravehicular capability.

4.1.2 Life Support Systems Development: This activity consists of the development of suits, environmental control systems, communication systems, and bioinstrumentation systems to provide the capabilities to support the various EVA tasks (assembly, maintenance, and repair, etc.). The activity shall insure that basic research and subsystem developments are programmed. It shall result in a program definition detailing hardware development programs, basic research, and subsystem developments and how they support the development of operational EVA capabilities.

4.1.3 Crew and Equipment Mobility Development: This activity consists of the establishment and implementation of a research,

development, and flight support program for the continuing evolution of crew and equipment mobility technology.

As the ultimate objective of activities implemented is the generation of data and hardware which will eventually be applicable to specific missions.

4.1.4 Work Site Technology Development: This activity shall insure that hardware development programs, evaluations, and experiments concerning restraint and stabilization aids (control momentum gyros, tethers, etc.), illumination aids, and tools are programmed to adequately support the EVA tasks. It shall consist of basic research in the areas of positioning aids for reduced gravity, astronaut performance during performance of EVA tasks, human performance in man-machine systems, etc.

A detailed program will be established to include ground-based simulations and zero 'g' evaluations of procedures, techniques, and hardware to development the work site aids necessary to allow a stable "platform" for the extravehicular crewman.

EVA REQUIREMENTS MAY BE FULFILLED BY COMMON
CAPABILITIES BUILT FROM THESE TECHNOLOGIES

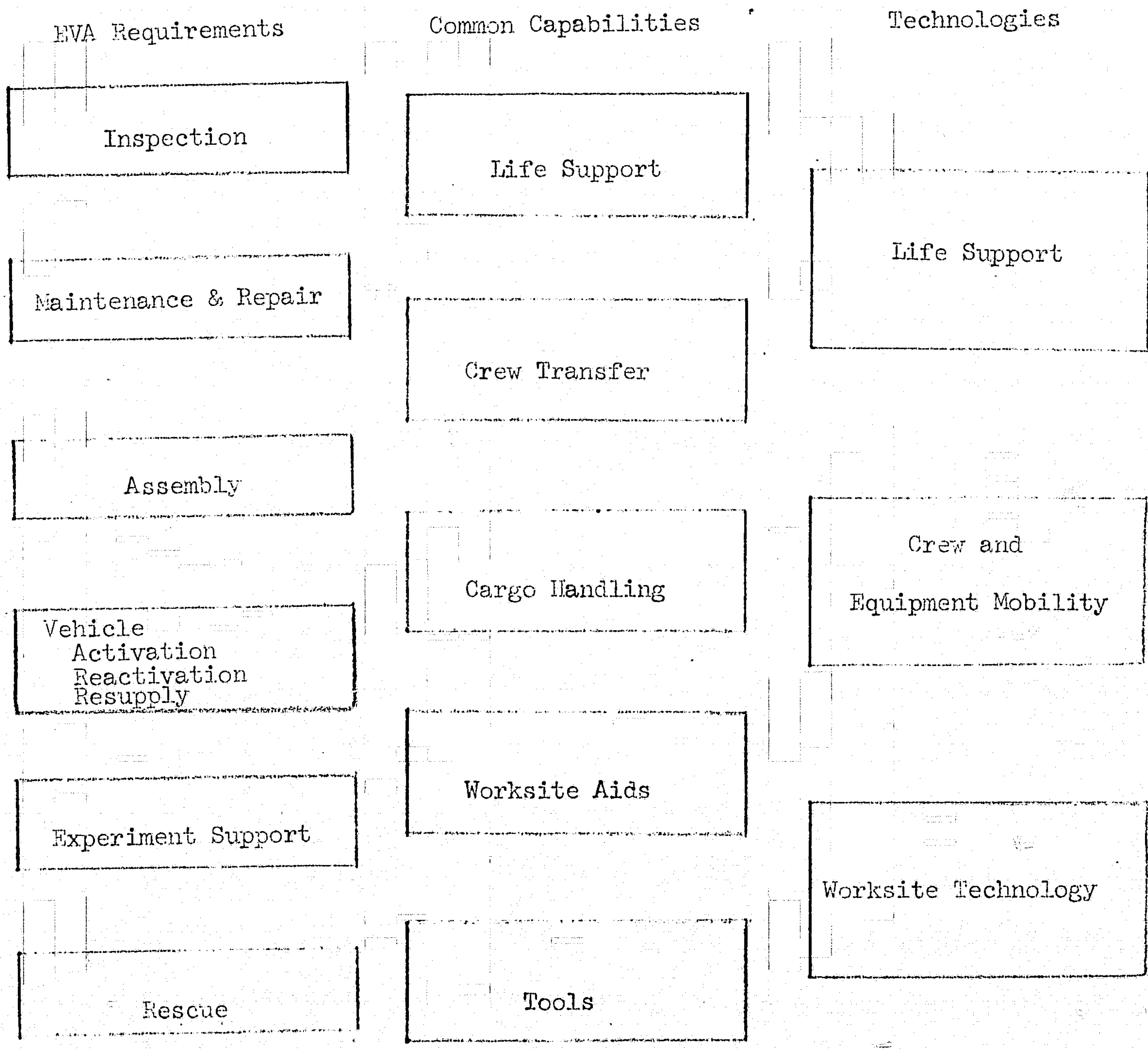

FIGURE NO. 1 - RELATIONSHIP OF REQUIREMENTS, CAPABILITIES & TECHNOLOGIES

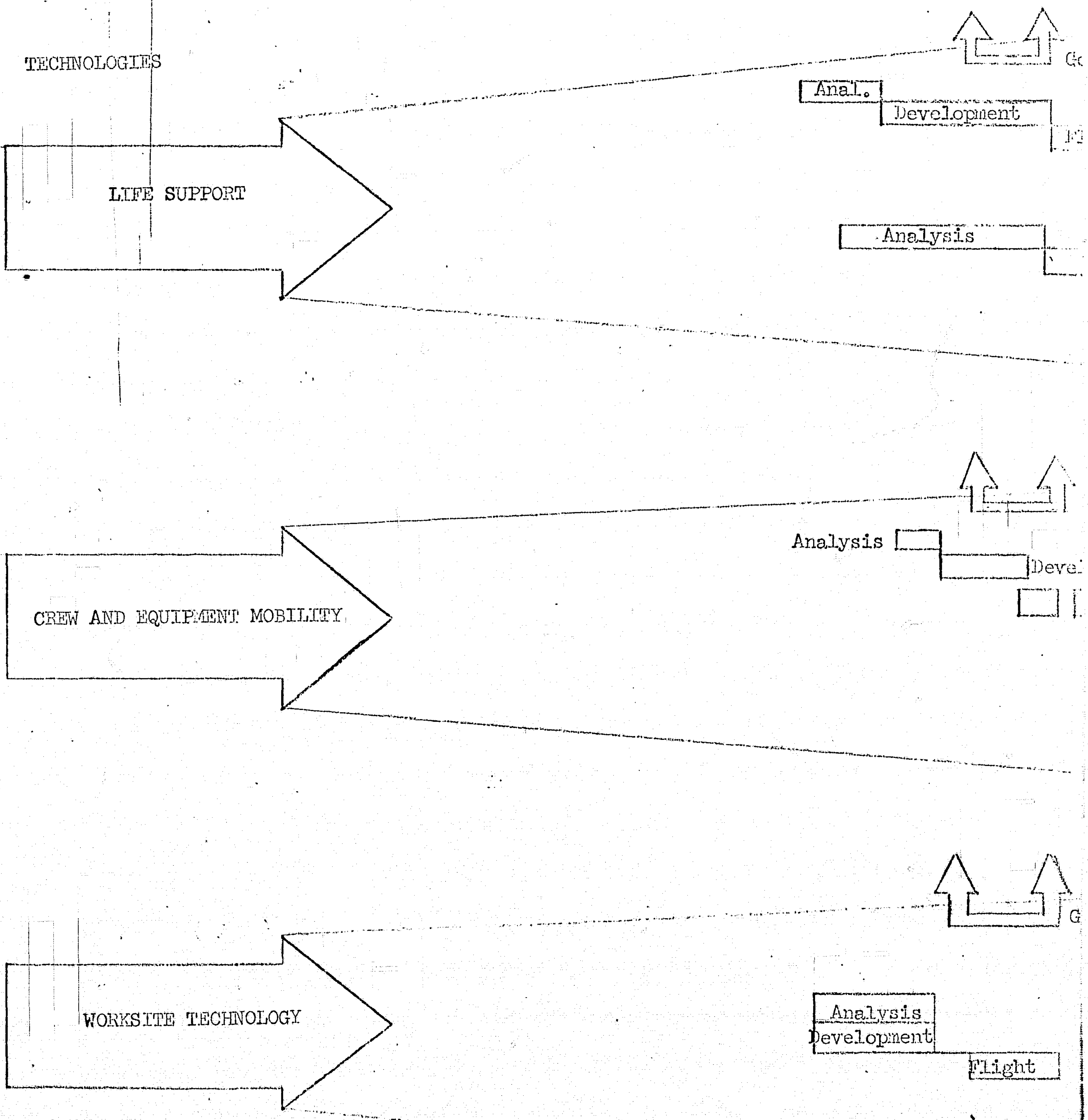

FIGURE 2. EVA TECHNOLOGIES
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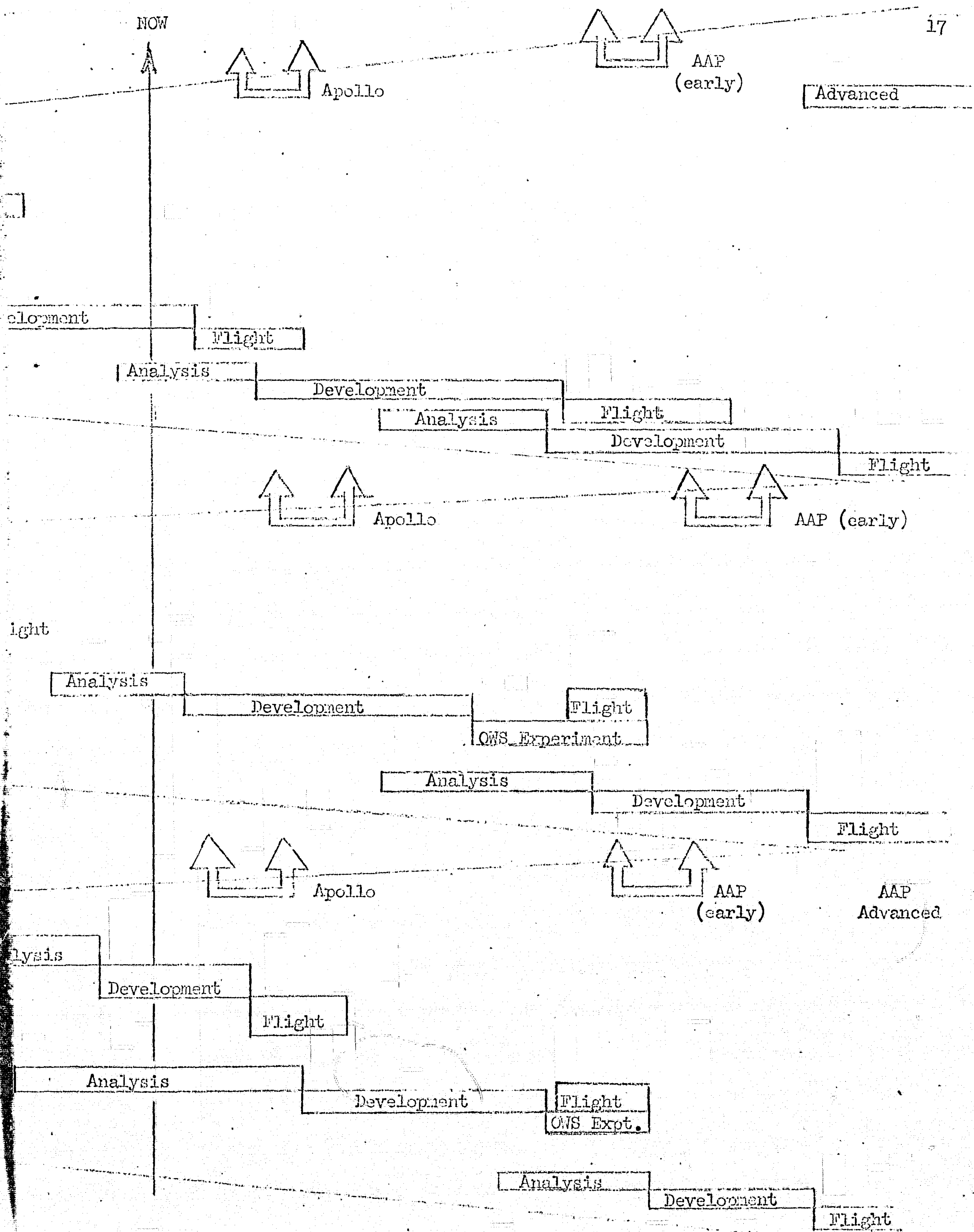

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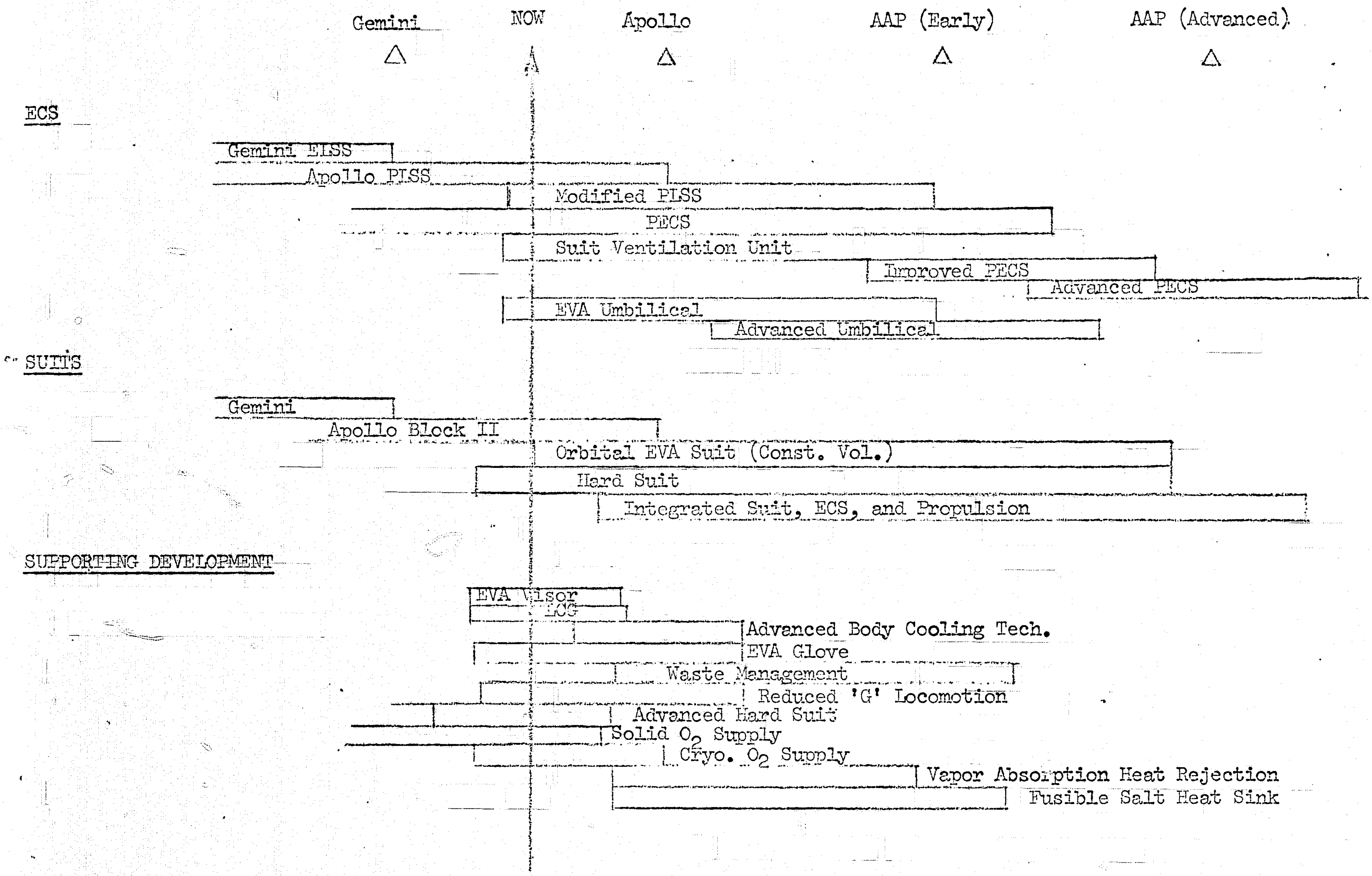

FIGURE 3. LIFE SUPPORT SYSTEMS DEVELOPMENT

APPENDIX 1

EVA TASK ANALYSIS

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APPENDIX 1

EVA TASK ANALYSIS

1.0 ORBITAL OPERATIONS:

1.1 Task Evaluations to Expand EVA Technology: The majority of major tasks such as activation, inspection, maintenance, and repair, etc., of orbiting structures can be broken down into discrete subtasks such as making and breaking electrical connectors, removing or attaching components, translating from one point to another, remaining in the desired attitude at a desired point, etc. The development of EVA as a useful operational tool should include a continuing program of evaluating these expected subtasks, both in one 'g' and in zero 'g'. A major portion of the extravehicular activity performed on the Gemini XII mission was devoted to this type of evaluation.

The desirable program for developing EVA subtasks, tasks, and procedures should consist of the following steps:

a. Determination of general requirements
b. One 'g' walkthroughs and evaluations
c. Neutral buoyancy evaluation
d. Possible zero 'g' evaluation in aircraft
e. Zero 'g' evaluation in pressurized orbital workshop
f. Zero 'g' evaluation or performance in the space vacuum

1.1.1 Ground-Based Simulations: As major tasks and resulting subtasks are defined for particular missions, ground-based simulations (one 'g' walkthroughs and neutral buoyancy evaluations) should be performed to determine the optimum method of accomplishing the subtasks as well as station aids, mobility aids, and tools required to accomplish the task. These requirements then should be integrated into neutral buoyancy simulations to evaluate the major task and all ancillary equipment and procedures to accomplish the task.

1.1.2 Zero 'G' Experiments: Certain experiments are to be performed during the first S-IVB OWS mission to investigate certain aspects of EVA or to investigate activities or equipment directly applicable to EVA. These experiments are to be

performed in the pressurized workshop; but the environment, with the exception of the ambient temperature and pressure, will duplicate the conditions experienced during EVA.

Extensive use of the OWS (Mission A, B, and future) to evaluate sub-tasks, mobility aids, tools, procedures, etc. should be made in order to take advantage of the relative safety of the pressurized workshop. This, then, is a logical extension of the ground-based simulations previously discussed.

a. Maneuvering Systems Evaluation: Several personal maneuvering systems will be evaluated during the first OWS mission. Each of these systems is expected to offer unique features applicable to particular tasks, and it is expected that the experiment tasks will be developed such that these features will be defined. In addition, limitations associated with each unit will be defined. The experiment will investigate translation, attitude control, and station-keeping as a minimum.

b. Worksite Aids (Restraints and Tethers) Evaluation: Gemini IX-A EVA experience underscored the need for extensive evaluation of methods of restraint required to maintain body position during EVA. An effective means of maintaining body position is a prerequisite to the performance of useful work in zero 'g'. Additional evaluations similar to that done on Gemini XII will be performed on a continuing basis (beginning with AAP Mission 1 and 2) as new techniques such as capsular and magnetic adhesive restraints and tension reel tethers are developed.

c. Crew Transfer Devices Evaluation: Crew transfer devices, apart from the maneuvering systems previously cited, are required in certain situations. The handrails installed on the Gemini adapter section, the portable handrail installed by the extravehicular crew-man to traverse from the hatch to the docking adapter on Gemini XII are examples of previously proven techniques.

Advanced concepts such as the "Fireman's Pole," Extravehicular Crew Transfer Device (EVCTD), and the Wire Gun shall be evaluated in the OWS and future vehicles on a timely basis.

d. Tools: The type of tasks which can be performed effectively will depend in a large part on the type of tools required for the task and the development of those tools. Very little experience with tools was accumulated during the Gemini Program. Experiments designed to evaluate various advanced concepts of space tools should be included as early as possible in the Apollo and Apollo Applications programs. By necessity, tools will be developed on an operational basis to meet the needs of experiments and operational requirements as they dictate.

Tasks	1. Evaluate subtasks 2. Evaluate procedures 3. Evaluate maneuvering and maneuvering systems 4. Evaluate worksite aids such as restraints and tethers 5. Evaluate crew transfer devices (nonpropulsive) 6. Evaluate tools
Equipment Required	NOTE: The hardware required to support the experiments (in addition to the hardware being evaluated) depends on the environment in which the experiment is to be performed, i.e., EVA or IVA. EVA: The total system required to support EVA experiments will consist of the following: a. Space suit assembly including LCG, thermal, and micrometeoroid protection. b. Life support system including umbilical, if required. c. Ancillary equipment as required such as stability augmentation (restraints, tethers, maneuvering aids), tools, crew transfer devices, etc. IVA: The systems required to support IVA experiments which evaluate EVA procedures and hardware are as follows:

Equipment Required (cont'd)	a. Space suit assembly including LCG b. Pressurization and ventilation control system c. Umbilical including oxygen and cooling water lines d. Ancillary equipment (as above)

1.2 Direct Experiment Support: All EVA presently programmed for AAP Missions 1 through 4 is in direct support experiments D-021, D-022, M-469, T-017, T-021, T-023, and the LM/ATM. The great majority of EVA performed on future missions will also be in direct support of experiments. Certain of these experiments require EVA for accomplishment, and certain experiments require EVA for data or material retrieval such as the LM/ATM film cassette retrieval.

The tasks listed below, though primarily in support of particular experiments, will provide significant data and information for the evaluation of more extensive tasks. For instance, installation and alignment of camera include subtasks directly applicable to maintenance and repair or erection of more complex structures.

Tasks	1. Install and align cameras 2. Deploy and/or retrieve meteoroid panels and emulsion panels 3. Retrieve and replace film cassettes 4. Change camera filters and exposure time 5. Remove and retrieve spacecraft components for return and analysis (i.e., T-019 Pegasus panel retrieval)
Equipment Required	1. Space suit assembly including LCG, thermal, and micrometeoroid protection 2. Life support system including umbilical 3. Stability augmentation such as: a. Tethers and station aids at the experiment site b. Handrails or maneuvering aids to permit transfer to and from experiment site

1.3 <u>Activation and Reactivation of Dormant Vehicle and Resupply of Active Vehicles:</u> The Apollo Applications Program is developed around the establishment of various "clusters" or modules to establish, in effect, space stations or orbiting laboratories. This concept dictates the capability to activate or reactivate the various dormant modules of the "cluster" and to provide a resupply capability for the extended missions.

Presently, the AAP 1 through 4 missions' activation, reactivation, and resupply is to be performed with the spacecraft, except for contingencies. Also, an EVA capability may be required should the automatic solar panel deployment mechanism fail. Although no definite requirement for EVA in these instances has been identified, none the less, it is felt that the capability should be developed in a timely manner with the expectation that for some of the later missions, the capability will be required.

Development of these capabilities can evolve from the normal transfer of equipment between the CM, Airlock, OWS, and LM/ATM of AAP missions 3 and 4 and from the installation of various portable handrails and umbilicals during the normal course of the early AAP missions.

Task	1. Transfer of cargo from one module to another 2. Installation of external umbilicals for Manned Orbital Solar Telescope (MOST) and Manned Orbital Telescope (MOT). 3. Solar panel deployment (normal or contingency)
Equipment Required	1. Space suit assembly including LCG, thermal garment and micrometeoroid protection 2. Life support system including umbilical 3. Stability augmentation a. Station aid such as tethers, "Dutch Shoes" b. Handrails to ease cargo transfer

1.4 Inspection of Orbiting Vehicles:

Inspection of orbiting vehicles covers a wide range of application; from cursory inspection prior to activation of dormant vehicles to the possible inspection and photography of satellites.

As mission duration and module complexity increases and as the requirement for maintenance and repair is established, it is felt that a planned program of periodic inspection, similar to that in aircraft applications, is desirable.

Task	1. Inspection of satellites 2. Inspection prior to activation of dormant vehicles 3. Periodic inspection of long duration space stations 4. Inspection or monitoring of systems deployment 5. Monitoring the condition of experiment panels (i.e., micrometeoroid and emulsion) 6. Inspection of suspect systems in case of failures (i.e., thrusters, solar panels and thermal coatings)
Equipment Required	1. Space suit assembly including LCG, thermal, and micrometeoroid protection 2. Life support system (both independent and umbilical dependent) 3. Tether attach points, "Dutch Shoes," or handrails to support inspection performed through the spacecraft 4. Provisions for these stations and mobility aids could be predetermined based on the periodic inspection plan 5. Stabilized maneuvering unit

1.5 Maintenance and Repair: It is inevitable that failures will occur during extended orbital operation of complex systems. Long duration missions require a new and different approach to service, maintenance, and repair activities to successfully achieve the mission objectives. The capability to accomplish maintenance, repair, and other activities must be conceived, designed, and developed into equipment concepts from their conception. Complete systems redundancy is one method of minimizing the impact of these failures. Another method is to design each system on a modular basis such that component replacement is a simple process and carry a supply of spare parts. The optimum method is probably a combination of the two. One and two year missions with resupply capability will tend to make replaceable modules more competitive. Simple maintenance and repair is already programmed in that the Portable Life Support System (PLSS) required H_2O recharge battery and LiOH bed replacement.

Task	1. Replacement of faulty sections of solar panel 2. Replacement of thermal or radiation shields 3. Replacement of radiator segments 4. Clean optical surfaces 5. Realignment of orbiting telescopes 6. Replace modular components 7. Repair of scientific satellites, where economically feasible, (including any of the above) after satellite capture 8. Repair damage done by micrometeorite 9. Manual activation of solar panel if automatic system fails
Equipment Required	1. Space suit assembly including LCG, thermal garment, and micrometeoroid protector 2. Life support system including umbilical 3. Maneuvering/stabilization unit 4. Crew transfer devices 5. Tools

1.6 <u>Erection of Orbiting Structures</u>: Some of the more advanced mission concepts propose the assembly of large structures in orbit; not only large space stations, but large antennas, solar cell arrays, and assembly, checkout, and launch of scientific payloads. Though no definite mission requiring this type of operation has been scheduled, the techniques to accomplish the erection of structures will be developed as the foregoing tasks are developed. In addition, certain experiments such as D-021 and D-022 to be flown on AAP missions 1 and 2 will provide information on expandable structures techniques. Activation of dormant vehicles, installation, and alignment of cameras, repair of thermal and solar panels, connection of external umbilicals, set-up of experiments, all these tasks and subtasks will develop capabilities required for the erection of orbiting structures.

Task	1. Large space station 2. Antennas 3. Solar cell arrays
Equipment Required	1. Space suit assembly, including LCG, thermal, and micrometeoroid protection 2. Life support system (both independent and umbilical dependent 3. Stability augmentation (tethers, restraints, and station aids as well as stabilized maneuvering system) 4. Tools 5. Cargo transfer aids

1.7 Crew Transfer:

Crew transfer will be required in support of the above tasks as well as for rescue and retrieval. Crew transfer about the exterior of a vehicle or cluster will be accomplished primarily by handrails (both fixed and movable); however, maneuvering systems will be required for transfer from one orbiting vehicle to another unless the attitudes of the vehicles can be controlled such that an extendable structure such as the EVCTD can be utilized.

A free space transfer from the LM/ATM to the CM in the event that one or the other cannot lock to the MDA is a contingency plan for AAP-4.

Techniques and equipment must be developed on a timely basis to meet these requirements.

Equipment Requirements:

The equipment required to accomplish crew transfer tasks includes the space suit assembly, a life support system capable of independent operation, i.e., no umbilical supplies from the spacecraft, and the necessary transfer devices to accomplish the crew transfer.

2.0 PLANETARY SURFACE EXPLORATION:

2.1 Unmanned Probes: As a forerunner to manned planetary surface exploration, the unmanned, scientific probe will be necessary in order to determine many of the unknowns surrounding the various planetary environments. Many of the initial questions to be answered prior to landing a manned surface expedition and establishing permanent bases can only be answered with any significant accuracy through the use of scientific probes.

Time Frame	1969 - 1973+
Mission Type	1. Flyby scientific probes 2. Orbiting scientific probes 3. Soft-landing scientific probes
Tasks	1. Measurement of planetary magnetic field 2. Determine composition and structure of the atmosphere 3. Observe surface topographical features 4. Radar mapping 5. Measure surface temperatures 6. Measure surface bearing strength and hardness 7. Measure solar flux conditions, etc.
Equipment Required	1. Mariner 2. Orbiter 3. Ranger 4. Surveyor, etc.
Pre-requisites	1. Testing and evaluation of scientific data gathering systems (scanners, recorders, etc.) at ground-based and earth orbital conditions.

2.2 Initial Manned Exploration: The initial manned surface exploration of an extraterrestrial body is represented by the Apollo lunar landing program. Preliminary investigations of local landing sites will be concerned with short-term manned excursions from the parent vehicle in order to photograph prominent terrain features, set up remote, self-contained scientific data collection devices, and to collect geological samples.

Time Frame	1969 - 1970+
Mission Type	1. CSM/LM (single launch) 2. Short-time stay surface excursions (1-4 hours per excursion 3. Short surface range (up to 2 miles)
Equipment Required	1. Space suit a. Block II and/or advanced soft suit 2. Life Support System a. PLSS 3. Locomotion System a. Astronaut walking, short range (single launch) b. Short range wheeled vehicle c. Lunar Flying Unit (LFU) - utility use, within short range 4. Geological sampling tools and survey equipment
Pre-requisites	1. Acquisition and evaluation of scientific data from unmanned probes 2. Adequate ground-based simulation testing and training in performing mission profile tasks a. One 'g' b. KC-135 flights c. Underwater d. Orbital Workshop (possible later spin-ups)

2.3 Extended Surface Exploration: Manned surface explorations will be extended from short periods of stay time and relatively close-range local site surveys to those of greater stay time and surface range. These extended surface missions will in all probability be the deciding factors in determining the establishment of permanent surface shelters or bases.

Time Frame	1970 - 1980+
Mission Type	1. Single launch vehicles a. CSM/LM b. CSM/ELM c. CSM/ALM 2. Dual launch vehicles a. CSM/ELM b. CSM/ALM c. CSM/LPM 3. Long time stay surface excursions (8 hours - 14 days/excursion) 4. Medium - long surface range (up to 240 miles)
Tasks	1. Extended surface explorations and surveys 2. Surface testing of advanced equipment for the establishment of permanent shelters and/or bases
Equipment Required	1. Space suits a. Block II and/or advanced soft suit b. RX hard suit 2. Life support system a. PLSS b. PECS 3. Locomotion system a. Astronaut walking, short range (up to 2 miles) b. LSSM, short - medium range, up to 15 miles (single/dual launch) c. LFU, medium - long range, up to 36 miles (single/dual launch) - one man system

Equipment Required (cont'd)	d. MOLAB, medium - long range, up to 240 miles (dual launch) - two-man environmentally controlled mobile vehicle for 14-day mission 4. Tools a. Repair (conventional/special purpose) b. Geological sampling 5. Emergency equipment a. Inflatable survival shelter b. Spare backpacks
Pre-requisites	1. Acquisition and evaluation of scientific data due experience gained from initial manned surface explorations 2. Adequate ground-based simulation testing and training in performing mission profile tasks a. One 'g' b. KC-135 flights c. Underwater d. Orbital Workshop (possible later spin-ups)

2.4 Equipment Deployment: The mission objectives of equipment deployment encompass the techniques of delivery and transference of those pieces of hardware that will enable the astronauts to successfully accomplish extended planetary surface operations (surface exploration and erection of permanent shelters/bases).

Time Frame	1970 - 1980+
Mission Type	1. Dual launch vehicles a. CSM/ELM b. CSM/ALM c. CSM/LPM d. CSM/LM taxi 2. Short - medium surface range (2 - 15 miles), small loads (10 - 100 lbs) 3. Medium - long surface range (15 - 240 miles), large loads (greater than 100 lbs) 4. Resupply and crew rotation

Tasks	1. Delivery and transfer of surface exploration equipment, mobility systems, and shelters 2. Unloading and assembly of surface exploration equipment, mobility systems, and shelters
Equipment Required	1. Space suit a. Apollo Block II and/or advanced soft suit b. RX hard suit 2. Life support system a. PLSS b. PECS 3. Locomotion system a. Short - medium surface range (2 - 15 miles), small loads (10 - 100 lbs) (1) Handcarry (10 - 25 lbs) (2) Backpack carrier (25 - 50 [illegible]) (3) Sled/travois/cart (50 - 100 lbs) b. Short - medium surface range (2- 15 miles), heavy loads (greater than 100 lbs) (1) Wheeled/tracked vehicle (a) LSSM (2) Flying vehicle (a) LFU c. Medium - long surface range (15 - 240 miles), all loads (1) Wheeled/tracked vehicle (a) LSSM (b) MOLAB (2) Flying vehicle (a) LFU 4. Tools a. Conventional and special purpose 5. Emergency equipment a. Inflatable survival shelters b. Spare backpacks

Pre-requisites	1. Acquisition and evaluation of scientific data and practical experience gained from previous initial and extended surface operations 2. Adequate ground-based simulation testing and training in performing mission profile tasks a. One 'g' b. KC-135 flights c. Underwater d. Orbital Workshop (possibly later spin-ups)

2.5 Permanent Surface Structures: All preceding efforts resulting from the initial surface surveh mission through those of extended explorations should ultimately result in the establishment of permanent surface structure. These permanent bases will then enable man to exploit the resources of the planetary surface.

Time Frame	1980+
Mission Type	1. Dual launch vehicles a. CSM/LPM b. CSM/LM taxi - shelter 2. Interplanetary vehicles
Tasks	1. Surface shelter (two weeks duration), 2 - 4 man capacity a. Used for limited surface excursions b. Emergency survival until rescue can be effected 2. Surface bases (1 month - indefinite period), 20 - 50 man capacity (stationary) a. Used for daily surface excursions

Equipment Required	1. Space suit a. Apollo Block II and/or advanced soft suit b. RX hard suit 2. Life support system a. PLSS b. PECS 3. Locomotion system a. LSSM b. MOLAB c. LFU 4. Surface shelter (2 - 4 man capacity) a. LM taxi - shelter (stationary) b. Inflatable shelter (portable) c. Repressurization capabilities (limited) 5. Surface base (stationary); 20 - 50 man capacity a. Large, inflatable structure b. Foamed-in-place structure c. Rigid, panel structure (prefabricated) d. Repressurization capabilities (extensive) 6. Tools a. Conventional and special-purpose b. Routine inspection and maintenance 7. Resupply of expendables and crew rotation
Pre-requisites	1. Acquisition and evaluation of scientific data and practical experience gained from previous extended surface operations 2. Adequate ground-based simulation testing and training in performing mission profile tasks a. One 'g' b. KC-135 c. Underwater d. Orbital Workshop

2.6 Planetary Surface Escape System: It is possible that emergency surface escape systems will be developed in the future for the purpose of rescuing disabled or marooned astronauts.

Time Frame	1970 - 1980+
Mission Type	1. Emergency surface escape and return to orbiting mother vehicle
Tasks	1. See Mission Type
Equipment Required	1. Standby LM-type vehicle on surface 2. Self-deployed flying vehicle system a. LFU 3. Descent/ascent vehicle from mother vehicle
Pre-requisites	1. Basic data from operational vehicle systems 2. Adequate ground-based and reduced gravity simulation a. One 'g' b. KC-135 flights c. Underwater d. Orbital Workshop